Got Protection?

Embedded Terrain Awareness Warning System
(eTAWS)

Adventures in testing a CFIT protection system

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What is eTAWS?

A Software algorithm

Data inputs come from onboard sensors

Velocities and Attitude

Height above Terrain

- Radar altimeter

- MSL altitude minus DTED

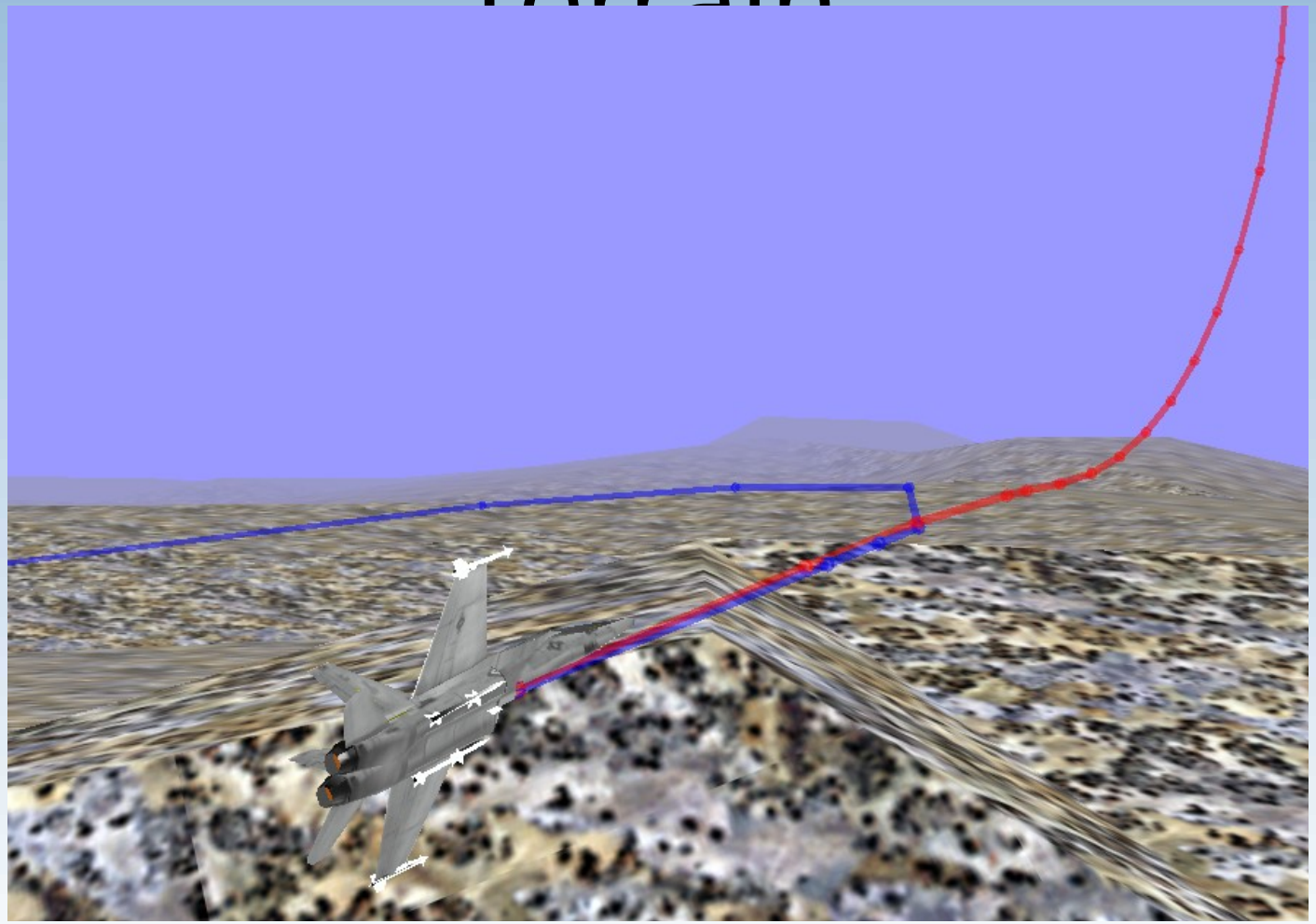
Provides visual and aural cues to pilot when CFIT is imminent

eTAWS has 2 Goals

Protect airplane and crew against CFIT

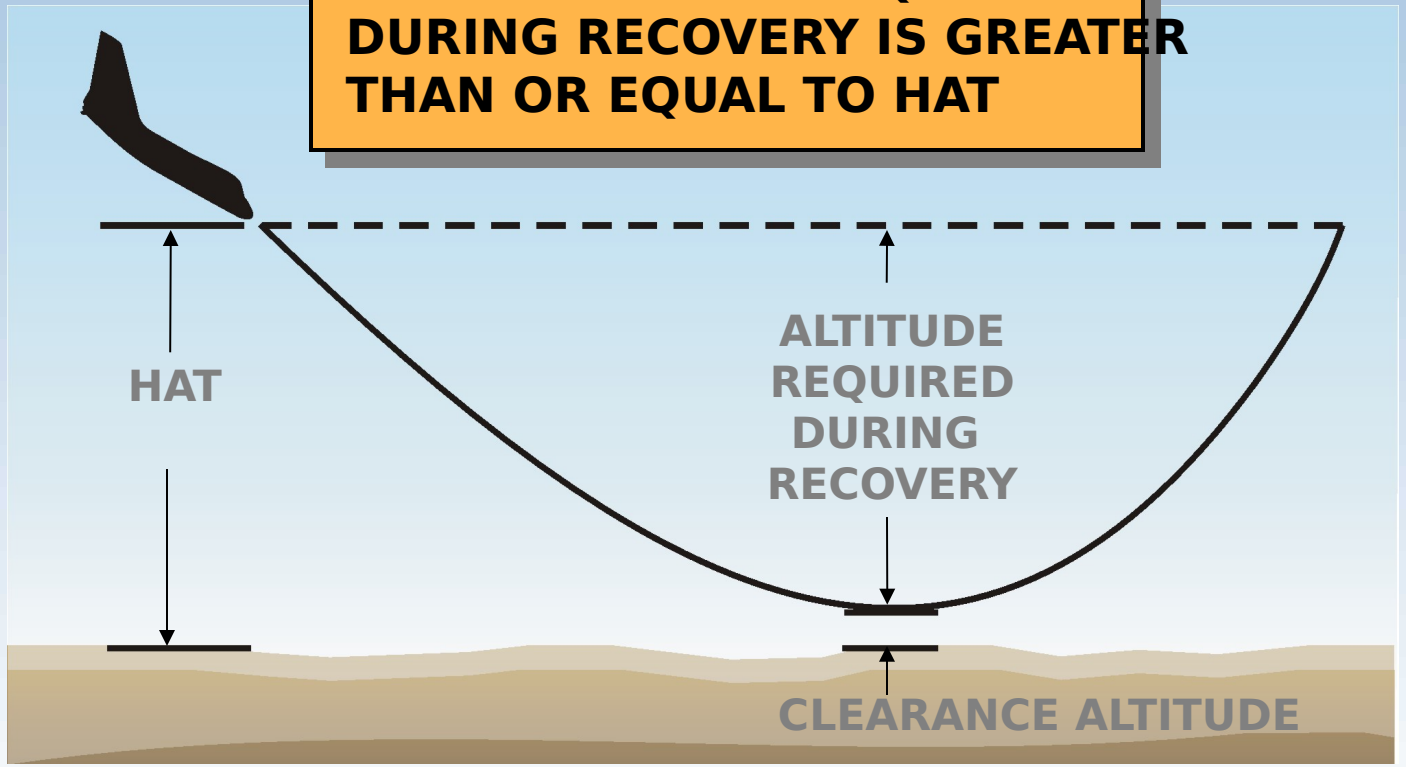
Allow situationally aware pilot to fly missions without getting unnecessary “nuisance” warnings

Trajectories overlaid on terrain



Recovery Trajectory

WARNINGS ARE ISSUED WHEN TOTAL ALTITUDE REQUIRED DURING RECOVERY IS GREATER THAN OR EQUAL TO HAT



Aural Cues

Pull-Up

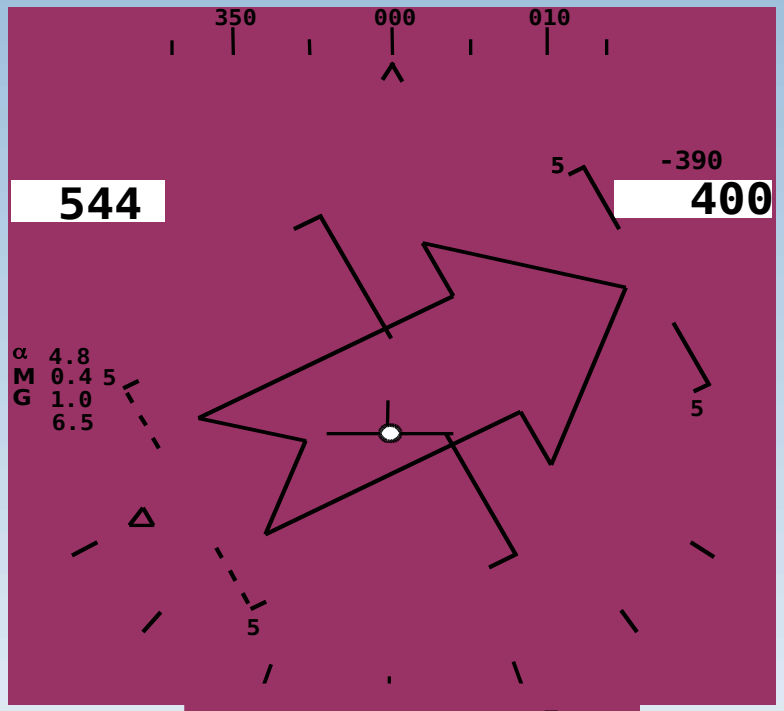
Roll Right

Roll Left

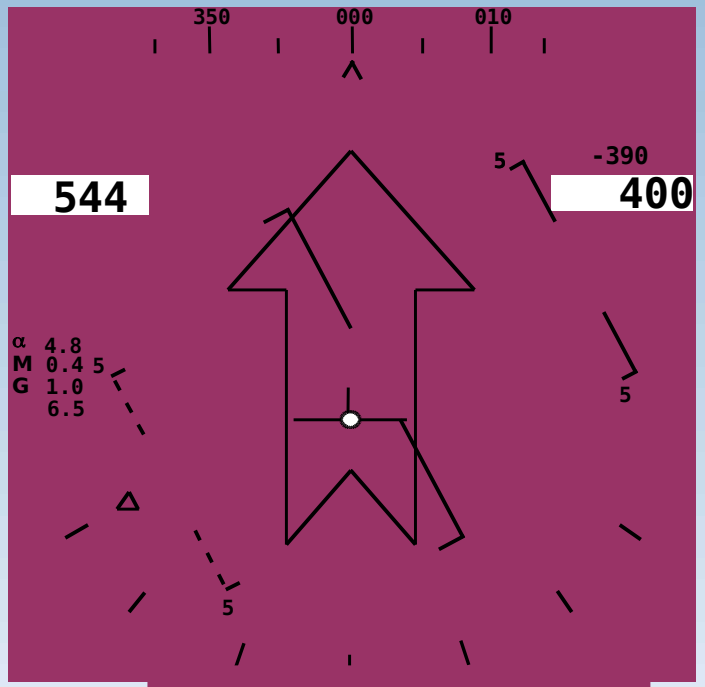
Power

Check Gear

Visual cue – arrow on HUD



vertical trajectory

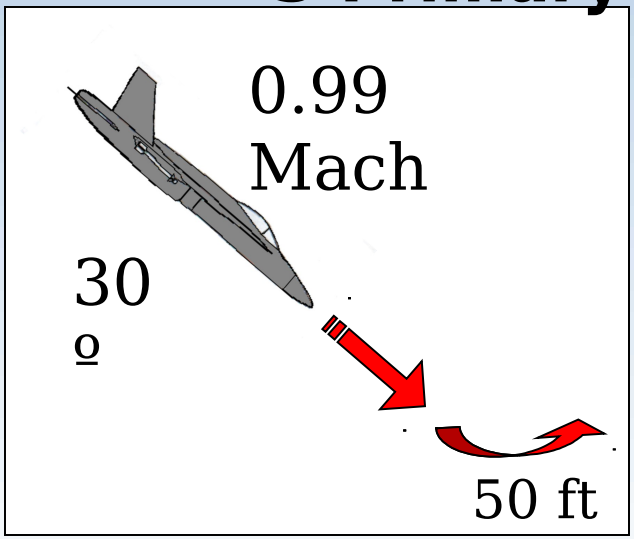


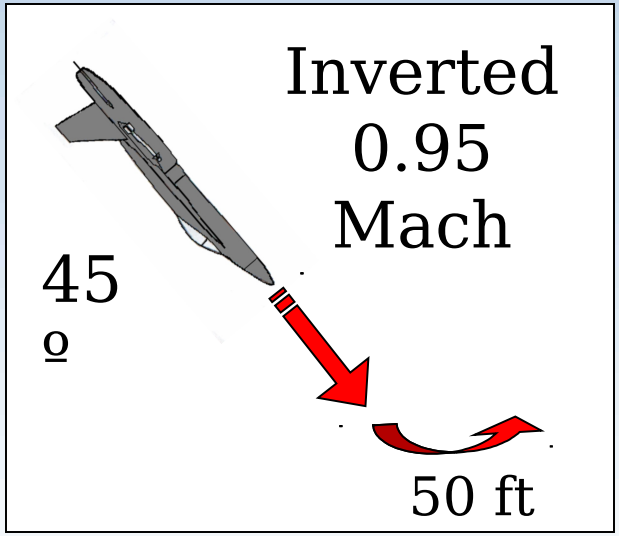
oblique trajectory

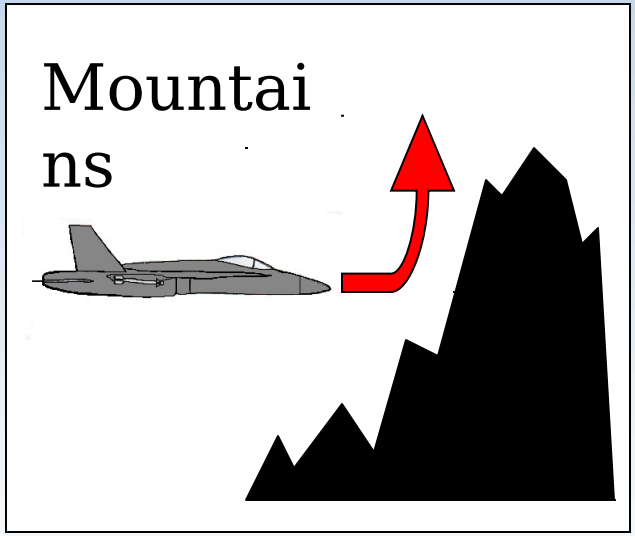
Test Methodology and Approval

- **Software Testing Complete**
  - **Regression and Integration testing**

- **Critical Flight Test Points**
  - 3 Primary areas







STOP

OK, Reality…

- Need to verify TAWS operation
  - Can’t kill anyone
  - Significant data required
- Simulation a requirement
  - No physical risk
  - Can’t answer all questions
- Proof is in the pudding – flight test a must!
  - Expensive, time-consuming, see #1 above

Test Approach

1. Basic Software Checks
2. Simulation
3. Flight Test
4. Analysis
5. Re-Stimulation
6. Change Software

Why Simulate?

Can create pseudo loss of situational awareness

Can SAFELY test ability to avoid CFIT

Compare performance in simulator with that expected by static eTAWS model

Results from CFIT protection testing in simulator have been very similar to those achieved in flight; enhances confidence and sample size.

MUCH cheaper and faster!

Why Simulate? (continued)

Allow for pilot set-up technique, maintain profi
during flight test delays

System not working? Leaves time prior to fligh
for investigation and modifications

Check for realistic test points; if the pilot cann
the point in the sim, don’t bother testing in flig

Some profiles very difficult to achieve in flight,
can be done in the simulator (example: vertical fl

Why not Simulate?

- Well, it's a simulator
- Vehicle motion is artificial
  - Perfect, when the system may not be
- An extra set of assumptions
- Pilot cueing different (if not wrong)

Flight Testing

- Two Types:
  - Performance testing
    - Does the system save me?
  - Nuisance Cue evaluation
    - Are there excessive false warnings?

Performance Test

- The hard part
  - How do you dive at the ground but not risk crashing?

“The trick to flying is throwing yourself at the ground, but missing…”

Douglas Adams

Performance Test

- Flying to actual warnings far too dangerous
- But, need representative flight conditions

- **Use a “buffer”, a false altitude signal !**
  - Makes system think ground higher than it is
  - Permits flight in similar conditions
  - Pilot selectable values
  - Allows for a recovery maneuver if warning is late
  - Aircraft flies below artificial ground = “crash”

Performance Test w/Buffer

- 2 Modes derived
  - Insert false altitude
    - Allows pilot to visually correlate obstacles
    - Provides variable clearance – most realistic
      - Steeper dives = more clearance required
  - Build a “false world” into DTED database
    - Easy to implement
    - More difficult to judge performance
    - Less control over terrain clearance

Performance Test - SAFETY

Monitor the flights!

Displays at ground station
- Real-time profile information
- Abort if minimums busted
- Ensure proper set-up for CFIT protection points

Safety chase / Back seat pilot for low level ops

Re-stimulation of test data

Record flight test data

Analyze data, propose changes

Play data back through modified software mo

Record performance achieved with modified software

Re-stimulation of test data

Allowed for faster implementation of software updates

- improved system performance
- elimination of problems

Flight tests	8/00	12/01
Software versions	5/01	10/01	3/02
Number of changes	7	11	3

Lessons Learned

- ***Safety Buffer was a flight test enabler***
  - Would never risk flight without
  - Allowed realistic test
- ***Re-Stimulation provided huge savings***
  - Orders of magnitude faster than flight test
  - Minimal cost to try variations + same conditions!!
  - Facilitates rapid software revision

Lessons Learned

- ***Re-Stimulation gave statistical significance***
  - Multiple flights too costly
  - Actual flight test data used repeatedly = better stats
  - Non-dedicated flights can be employed

QUESTIONS?

NAV AIR